CAN SUPPLEMENTAL FORAGING PERCHES ENHANCE HABITAT FOR ENDANGERED SAN CLEMENTE LOGGERHEAD SHRIKES?

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ABSTRACT.—Habitat degradation caused by feral grazers has been identified as a possible limiting factor for the endangered San Clemente Loggerhead Shrike (*Lanius ludovicianus mearnsi*). In 1999, we installed supplemental foraging perches within shrike breeding territories on San Clemente Island and observed shrike foraging behavior before and after perches were installed. Shrike foraging efficiency, determined by measuring foraging attack distances and success rates, was not improved when supplemental perches were present; however, shrikes shifted their focal foraging sites to areas where perches were installed. Shrike home ranges did not change size when supplemental perches were installed, indicating that foraging areas made available by adding supplemental perches were not of higher quality than those that were previously available. However, the addition of supplemental perches may have increased the total foraging habitat available to this endangered subspecies. *Received 13 May 2005, accepted 17 February 2006.*

Habitat deficiencies have been identified as possible limiting factors in populations of Loggerhead Shrikes (*Lanius ludovicianus*; Yosef 1994, Cade and Woods 1997). In the 1980s, Scott and Morrison (1990) studied a population of endangered shrikes on San Clemente Island (SCI), the San Clemente Loggerhead Shrike (*L. l. mearnsi*). In the late 1890s and early 1900s, Grinnell (1897) had considered this subspecies "tolerably common; that is, two or three could generally be seen during an hour's walk," and Linton (1908) called the population "fairly well distributed." By the 1990s, the population on SCI had dropped to a low of 13 individuals (T. Mader unpubl. data). Scott and Morrison (1990) identified habitat degradation attributed to overgrazing by feral goats (*Capra hircus*) as a likely cause of this subspecies' decline. Common effects of overgrazing by feral goats include depletion of woody species and an increase in exotic vegetation (Coblentz 1980).

Because shrikes use elevated substrates as foraging perches, from which they can readily see prey and attack with flights to the ground (Bent 1950), perches are an important component of shrike territories (Esely and Bollin-ger 2001). If elevated perches are lacking, shrikes may not be able to use all potential foraging habitat and may, therefore, increase their home-range size to encompass an adequate area of usable habitat. Having to move about larger home ranges and defend larger territories requires that shrikes expend greater amounts of energy; this may result in a decrease in their nutritional status (Yosef and Grubb 1992). The establishment of larger territories also decreases the shrike carrying capacity of SCI's limited area. Yosef and Grubb (1994) found that adding fence posts to shrike territories in Florida resulted in smaller average territory sizes and greater breeding densities of shrikes. Artificial perches have also been shown to attract raptors, especially kestrels (*Falco* sp.), to areas that were otherwise devoid of appropriate perches (Kay et al. 1994, Wolff et al. 1999, Kim et al. 2003).

Optimal foraging theory suggests that an animal will optimize the capture and consumption of prey, maximizing energy intake while minimizing energy expenditure (Schoener 1971, Mills 1979). Therefore, an increase in foraging efficiency should be reflected by shorter attack distances (less energy required to fly a shorter distance), capture of larger prey items (fewer attempts needed), and a greater percentage of successful foraging attempts (less wasted energy on failed foraging attempts). An increase in foraging efficiency also may be reflected by more frequent captures per unit time, even if success rate does not improve. Furthermore, shrikes may select nest locations near foraging areas to decrease energy expended in flight while tending a nest.

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Shrike foraging efficiency may be constrained by the number and arrangement of available hunting perches. Prior to our supplemental perch experiment, we had found a greater number of trees and shrubs at sites occupied by shrikes on SCI than at sites shrikes had abandoned within the past 10 years (SL unpubl. data). If hunting perches are limited, then it seemed reasonable to expect that the addition of supplemental perches within shrike territories would allow foraging efficiency to increase by providing shrikes a greater choice of hunting perches, thereby increasing their opportunity to choose the best hunting area. Therefore, we designed an experiment to determine whether the addition of supplemental perches to shrike territories would increase foraging efficiency and the effective usable area of a given home range. We also examined whether the presence of supplemental perches would alter shrike breeding behavior by allowing them to forage nearer to their nests.

METHODS

Study area.—San Clemente Island (32° 50′ N, 118° 30′ W), the southern-most of California's Channel Islands, is located about 100 km northwest of San Diego, California. The island is 28 km long (width = 3–7 km, area = 145 km²) and rises abruptly to 599 m in elevation on the eastern escarpment. Numerous canyons cut through marine terraces on the southwestern part of the island. Island temperatures range from 7–35° C, precipitation ranges from 12–20 cm/year (mainly November through March), and fog is common, especially in summer months (Jorgensen and Ferguson 1984, Scott and Morrison 1990).

Native vegetation on the island has been substantially altered by introduced herbivores, including sheep (*Ovis aries*), goats, and pigs (*Sus scrofa*), all of which were eradicated by 1993. By the time of our study, the dominant plant community comprised native and non-native grasses (including *Avena, Bromus*, and *Nassella* spp.) interspersed with areas of recently recruited coyote brush (*Baccharis pilularis*), which covered ~33% of the flatter upper reaches of the island (U.S. Department of the Navy 2001). Shrubs and trees were primarily restricted to the canyon bottoms. SCI is operated by the U.S. Navy as a training base, primarily for ship-to-shore bombardment in the area where we conducted our study. See U.S. Department of the Navy (2001) for additional information on the island's vegetation, geography, and other natural resources.

Site selection and study design.—In 1999, we selected four (of eight total) pairs of breeding shrikes on SCI for study. None of the pairs' home ranges overlapped, and the distance between the edge of each pair's home range and its closest neighbor ranged from 100–800 m. Sample size was constrained by logistical and conservation considerations, such as site accessibility and concerns about manipulating the breeding sites of a highly endangered population. We studied shrike behavior and recorded their responses to supplemental perches during two periods: 13 March through 4 June (period 1) and 5 June through 2 August 1999 (period 2). On 13 March, we installed supplemental perches at two sites (A and D; Fig. 1). During period 1, we observed at least 75 foraging attempts at the sites with supplemental perches and also at two sites (B and C; Fig. 1) without supplemental perches. On 5 June, we removed the perches from sites A and D and installed them at sites B and C; during period 2, we observed another 75+ foraging attempts at each site. This paired sampling design controlled for seasonal and individual differences in behavior.

The shrike breeding season typically begins in January with pair formation and extends through mid-August, when the last fledglings disperse from their natal territories. Because we were concerned that different breeding stages might elicit differences in foraging behavior, we recorded the shrikes' breeding stage throughout the study and mapped the locations of their nests. During the nestling and fledgling stages, shrikes may alter their foraging behavior by increasing foraging rates to provide for their young. Therefore, we eliminated foraging attempts observed during these periods to avoid biasing our results.

At sites B and C, the original females were replaced by captive-released females during the breeding season. The original female at site B disappeared between 11 and 17 April and was replaced with a released female on 1 May. We collected data on this female during both study periods. At site C, the original fe-
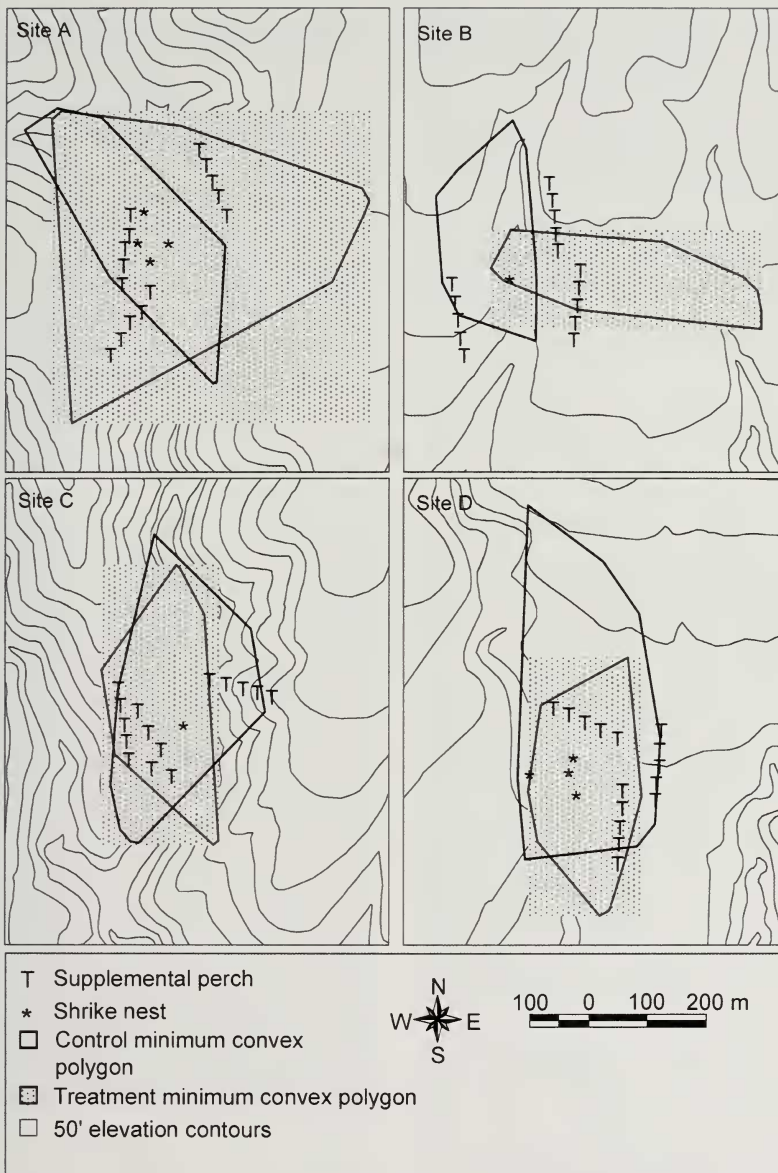
FIG. 1.   Maps of minimum convex polygon home-range estimates, encompassing all foraging locations, when supplemental perches were present (treatment) and not present (control) within San Clemente Loggerhead Shrike territories, San Clemente Island, California, 1999.

male was depredated between 2 and 5 May and replaced with a released female on 15 May, prior to the installation of supplemental perches at that site.

At all sites, we installed 3 groups of 5 supplemental perches, arranged linearly where possible (Fig. 1), for a total of 15 perches per site. Within a group of five, we spaced sup-

plemental perches 30 m apart, which was twice the average attack distance for a ground foraging attempt (SL unpubl. data), and >30 m from naturally occurring, elevated (>2 m) perches. We placed each line of perches at a randomly selected distance (1 to 200 m) from the shrike activity center at each site, and we oriented each line according to randomly se-

lected compass directions. Supplemental perches were poles of aluminum conduit (3 m long, 1.3 cm in diameter) slipped over a piece of rebar pounded into the ground. Attached to each pole were three horizontal cross pieces (40 cm long) made of wooden dowels (0.3 cm in diameter) positioned at 2.5, 1.5, and 0.75 m from the ground. Barbed wire was wound around the joint of the cross piece and upright conduit to serve as a site for shrikes to impale their prey.

Data collection.—We identified all shrikes by unique combinations of colored leg bands. Our observation points were >50 m away from the center of shrike activity to avoid disturbing the shrikes; at sites where one observation point was not sufficient to observe the entire area, we placed additional points at variable distances from the activity center. We observed each shrike pair for 0.5–1.0 hr per visit. In addition to bird identity and weather conditions, for each foraging attempt we recorded perch substrate, perch height, type of foraging maneuver (aerial sally, ground forage [flight to the ground from an elevated perch], or vegetation glean), outcome, foraging-attempt distance, and prey captured (mouse, lizard, bird, small arthropod [$\leq$10 mm, i.e., smaller than the length of a shrike bill], and large arthropod [>10 mm]). Because there were significant differences between male and female behaviors (i.e., the female is the primary incubator, the male provisions the female when she is on the nest), we analyzed foraging behavior separately by sex.

Statistical analyses.—We mapped the locations of perches used by shrikes during foraging attempts, then transferred these locations to ArcView, v. 3.2a (Environmental Systems Research Institute, Inc. 2000). We generated minimum convex polygons using ArcView Animal Movements Extension, v. 2.0 beta (Hooge et al. 1999) for locations mapped when supplemental perches were present (treatment: $n = 73–85$) and not present (control: $n = 80–94$). We used paired t-tests to compare the sizes of minimum convex polygons between treatments and controls. To determine whether shrikes shifted their foraging areas in response to the installation or removal of supplemental perches, we also mapped the locations of supplemental perches used by shrikes and then counted the number

that fell within the polygons generated during treatment and control periods. We used Fisher's exact test of independence (Sokal and Rohlf 1981) to compare the number of perch sites used during control and treatment periods.

To determine whether supplemental perches affected the selection of nest sites, at each site we recorded whether each nest was initiated during treatment or control. For nests initiated during treatment, we measured the distance from the nest to all supplemental perches. For nests initiated during control, we measured the distance from the nest to where the supplemental perches were installed during treatment. At sites where shrikes built nests during both treatment and control, we compared the mean nest-to-supplemental perch distance during treatment to the mean nest-to-supplemental perch distance for all supplemental perch sites (i.e., perch site = location where a supplemental perch would be, or had been, placed during treatment) during control. We used paired t-tests to ascertain differences in foraging-attempt distances between treatment and control. Where sample sizes were large enough, we used chi-square tests to test for treatment versus control differences in forage-maneuver type, foraging success, and size of prey item captured; otherwise we used Fisher's exact test. Because of inherent differences in foraging-maneuver type (i.e., larger prey items, such as lizards and mice, were not captured during aerial sallies), we analyzed size of prey and foraging-attempt distances by type of foraging maneuver. Means are reported $\pm$ SD. We considered $P \leq 0.05$ to be statistically significant.

RESULTS

We observed a total of 674 foraging attempts, 338 of which occurred during the treatment phase (110 from supplemental perches, 228 from naturally occurring perches) and 336 during the control phase of our study. After eliminating foraging attempts when nestlings or fledglings were present, we were able to determine whether a foraging attempt was successful for 447 attempts, 224 during treatment (86 from supplemental perches and 138 from naturally occurring perches) and 223 during control.

Pairs at sites B and C built and tended one

TABLE 1.   Distance between nests and supplemental perches installed within San Clemente Loggerhead Shrike territories, San Clemente Island, California, 1999. During control periods, distances were measured between nests and the pre-designated locations of supplemental perches, which were present only during treatment periods.

Site	Nest	Period when nest initiated	Distance to nearest supplemental perch	Mean distance ($\pm$ SD) to supplemental perches
A	A	Pre-study	41 m	118 $\pm$ 52 m
	B	Treatment	31 m	153 $\pm$ 63 m
	C	Control	121 m	274 $\pm$ 97 m
	D	Control	132 m	233 $\pm$ 68 m
B	A	Control	70 m	149 $\pm$ 61 m
C	A	Control	72 m	122 $\pm$ 35 m
D	A	Pre-study	80 m	119 $\pm$ 29 m
	B	Treatment	73 m	121 $\pm$ 27 m
	C	Control	111 m	145 $\pm$ 29 m
	D	Control	85 m	126 $\pm$ 31 m

nest each. Shrike pairs at sites A and D, however, each built and tended four consecutive nests, none of which were successful. One nest at each of these two sites was initiated during treatment (i.e., supplemental perches were present). Both of the nests initiated during treatment were closer to the nearest supplemental perch site than any other nests (Table 1). The mean distance from each of these two nests to all supplemental perch sites, however, was not shorter than that of nests initiated when supplemental perches were not present (Table 1). Shrike home-range size did not differ between treatment and control (treatment: 8.5 $\pm$ 6.1 ha; control: 7.7 $\pm$ 2.7 ha; t_3 = 0.24, P = 0.83). However, shrikes shifted their home ranges to include some of the supplemental perches when they were present. Significantly more of the supplemental perch sites were located within shrike home ranges
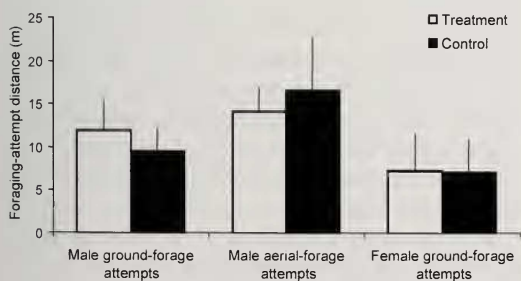

FIG. 2.   Mean $\pm$ SD foraging-attempt distances of male and female San Clemente Loggerhead Shrikes in territories with (treatment) and without (control) supplemental perches, San Clemente Island, California, 1999.

during treatment (n = 40) than during control (n = 32; P = 0.023, df = 3).

The addition of supplemental perches did not affect average distance of foraging attempts (Fig. 2). For male shrikes, attack distances for ground-foraging attempts were not affected by the presence of supplemental perches (n = 300, t_3 = 1.06, P = 0.37) nor were attack distances of aerial sallies (n = 140, t_3 = 0.59, P = 0.60; Fig. 2). Likewise, female attack distances for ground-foraging attempts were not affected by the presence of supplemental perches (n = 51, t_2 = 0.29, P = 0.79). We did not observe a sufficient number of vegetation gleans for analysis of attack distance. Also, the addition of supplemental perches did not result in altered proportions of foraging maneuver types used by males (n = 471, χ^2 = 0.48, P = 0.79, df = 2) or females (n = 70, χ^2 = 2.68, P = 0.10, df = 1; Fig. 3).

Foraging success of neither males (n = 327, χ^2 = 1.53, P = 0.22, df = 1) nor females (n = 52, χ^2 = 0.79, P = 0.38, df = 1) improved when supplemental perches were present (Fig. 4). Shrikes foraged from supplemental perches 33% of the time when they were present, and we found no difference in the proportion of successful foraging attempts launched from supplemental and naturally occurring perches (n = 224, χ^2 = 1.43, P = 0.23, df = 1). Although shrikes tended to capture more prey/hr when using supplemental perches (0.98 $\pm$ 0.48 successful foraging attempts/hr) than when using naturally occurring perches (0.52
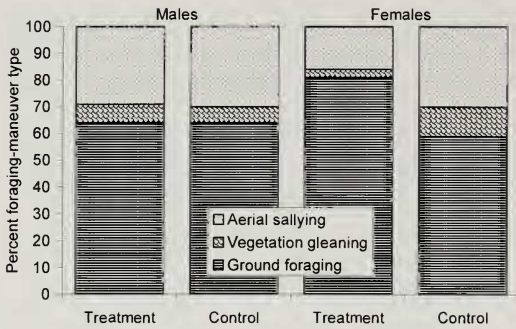
FIG. 3. Percentages of foraging-maneuver types performed by San Clemente Loggerhead Shrikes in territories with (treatment) and without (control) supplemental perches, San Clemente Island, California, 1999.
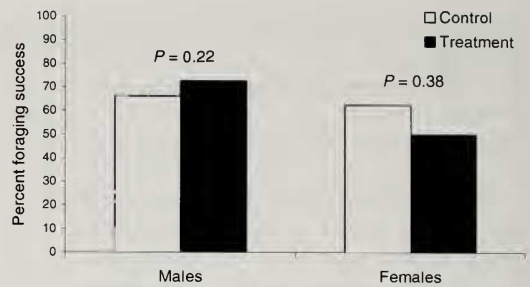

FIG. 4. Percent foraging success of male and female San Clemente Loggerhead Shrikes in territories with (treatment) and without (control) supplemental perches, San Clemente Island, California, 1999.

$\pm$ 0.15), the difference was not significant (n = 159, t_3 = 1.84, P = 0.16). Shrikes always perched on the top-most crossbar before foraging, and only once did a shrike use a lower crossbar—briefly, before moving up to the top crossbar.

During ground-foraging attempts, neither males (n = 95, χ^2 = 1.46, P = 0.23, df = 1) nor females (n = 14, Fisher's exact P = 0.46, df = 1) captured larger prey (small/large: males with supplemental perches = 33/19, males without supplemental perches = 22/21, females with supplemental perches = 2/2, females without supplemental perches = 7/3) when supplemental perches were present. During aerial sallies, however, males captured more small arthropods than large arthropods when supplemental perches were present (n = 93, Fisher's exact P = 0.007, df = 1; small/large: with supplemental perches = 43/3, without supplemental perches = 34/13). Vegetation gleans by males tended to yield smaller prey when supplemental perches were present (n = 22, Fisher's exact P = 0.08, df = 1; small/large: with supplemental perches = 8/5, without supplemental perches = 2/7).

DISCUSSION

Although many aspects of shrike foraging efficiency did not increase when we installed supplemental perches, San Clemente Loggerhead Shrikes responded positively to the presence of supplemental perches by increasing their use of the areas around the perches. Shrikes readily used supplemental perches, and we found that when supplemental perches were added to a home range, shrikes shifted their foraging habitat to include the area around some, but not all, of the supplemental perches. The one exception to this pattern was an apparent shift toward an area without supplemental perches that was burned by a late-season fire at site B.

The shift in areas used by shrikes when supplemental perches were present suggests that some areas of the shrikes' home ranges contained prey resources that could not be used due to a lack of appropriate foraging perches. Although our sample size was insufficient for statistical comparisons, the shrikes seemed to place their nests closer to supplemental perches when they were present (Fig. 1); if true, shrikes may have reduced their energetic costs by taking advantage of the newly available foraging areas. Tall perches may have provided other benefits to shrikes, including increased capacity for predator vigilance and more display areas for territory defense and mate attraction. In contrast, Chavez-Ramirez et al. (1994) found that shrikes in natural grasslands in Texas did not shift their foraging areas as densities of artificial perches were manipulated; instead, the shrikes increased their use of herbaceous perches, and Chavez-Ramirez et al. (1994) concluded that foraging perches were not a limiting factor in natural grasslands.

Habitat enhancement has yielded beneficial results where focal species lacked certain habitat components. In disturbed landscapes of Washington state (Rocklage and Ratti 2000), bird species diversity increased with the addition of irrigation along the Snake River and, in New Zealand, several bird species in-

creased their use of areas cleared of willows along braided rivers (Maloney et al. 1999). Probably due, in part, to the extremely low number of shrikes on SCI, we did not see a similar increase in bird density with the addition of supplemental perches. Consequently, the lack of intraspecific competition between San Clemente Loggerhead Shrikes allowed them to investigate areas that were previously unavailable and to respond opportunistically to novel structures. We did not find a concurrent increase in foraging success or efficiency with the addition of supplemental perches, indicating that the areas opened up for foraging by the addition of perches may not have been superior to those already available. This idea was supported by the substantial overlap in areas used during treatment and control periods (Fig. 1) and our observation that shrikes did not use all of the supplemental perches provided, both of which indicate that the habitat quality in some areas was poor and would not be enhanced even by the installation of supplemental perches.

Shrikes in Florida reduce their territory size with the addition of foraging perches, and new shrike pairs will establish territories in the areas vacated (Yosef and Grubb 1994). When a limited resource (foraging perches) is added, shrikes are able to decrease the energy expended on moving throughout and defending a large territory from other shrikes, thereby potentially improving their nutritional status (Yosef and Grubb 1992). With the decrease in territory size defended, and the density increase in pairs of shrikes, the addition of supplemental perches potentially increased the carrying capacity of shrike habitat in Florida.

Unlike shrikes in Florida, however, home-range size of San Clemente Loggerhead Shrikes was not affected by the presence of additional foraging perches. On SCI, the low number of breeding shrikes (eight pairs) negated the advantage of decreasing home-range size to reduce energy expenditure on territory defense. Shrike home-ranges were far enough apart (>100 m; T. Mader unpubl. data) that territorial defense against neighboring shrike pairs was unlikely to limit the home-range size of the resident pair. Furthermore, because the shrike population in our study was thoroughly observed and color-marked, we are confident that no additional shrike pairs were

breeding nearby; therefore, little competition for breeding resources could have occurred.

After the addition of supplemental perches, San Clemente Loggerhead Shrikes incorporated previously unused habitat while maintaining similarly sized home ranges, suggesting that other aspects of their home range were still important to their survival. Supplemental perches provided substrates on which to perch and impale captured prey, but did not provide the structure and foliage of trees—features required by shrikes for nest placement and for concealment and escape from predators. Kim et al. (2003) found that shrikes were more closely associated with natural woody perches than artificial perches and attributed this association to the lack of escape cover at artificial perches. In Kansas, the number of potential nesting trees was the most important predictive variable for shrike habitat suitability (Lauver et al. 2002). Trees and shrubs on SCI can attain heights of >10 m, but they are limited to canyon bottoms and other areas that were protected from goat herbivory. Nonetheless, shrikes must include these remnant trees and shrubs in their breeding home ranges for successful reproduction and survival.

In contrast to Yosef and Grubb (1994), we did not find evidence that the availability of suitable foraging perches limits shrikes energetically, possibly due to the differences in terrain between their study site and ours. Shrikes on SCI typically inhabit steep, rocky, topographically complex canyons, although they occasionally forage on flat mesas between canyons. In such topographically complex environments, short foraging perches may not limit the area available that shrikes can search for prey to the degree that they would in a flatter environment. Two of the shrike territories we observed were in typically rocky canyons, and two were in shallower canyons flanked by flat mesas. Our results suggest that there may be an interaction between foraging-perch availability and topography, although our sample size was insufficient to demonstrate this conclusively.

With recent increases in the shrike population resulting from intensive population management—including the release of captive-bred shrikes into the wild—competition may play a greater role in the choice of defended foraging areas. To accommodate an increasing

population, potential shrike habitat should be made available by the addition of hunting perches. Long-term improvement of shrike habitat should include restoring trees and shrubs to SCI to increase the availability of nesting habitat. Meanwhile, the lack of elevated hunting perches may be temporarily alleviated by the installation of artificial perches.

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